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Effects of Dynamometer Variability on the Confirmation of Requests for Alternate Dynamometer Power Absorption

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Technical Support Report for Regulatory Action

Effects of Dynamometer Variability on the Confirmation of Requests for Alternate Dynamometer Power Absorption

by

Glenn D. Thompson

March, 1978

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16. ABSTRACT

This report discusses the variations which have been observed among the EPA light-duty vehicle dynamometers during vehicle-dynamometer coast-downs. The purpose of this investigation is to recommend a tolerance value for the allowable variation between the "target" coastdown time interval, supplied by the manufacturer and the time interval obtained from the EPA vehicle-dynamometer confirmatory test. This tolerance is a measure of the acceptable error between the road experience of the vehicle as reported by the manufacturer and the simulation by the dynamometer during the EPA tests. As such the tolerance is a direct limit on the road load simulation error which EPA will accept and still consider the test results valid.

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I. Purpose

This report discusses the variations which have been observed among the EPA light-duty vehicle dynamometers during vehicle-dynamometer coastdowns. The purpose of this investigation is to recommend a tolerance value for the allowable variation between the "target" coastdown time interval, supplied by the manufacturer and the time interval obtained from the EPA vehicle-dynamometer confirmatory test. This tolerance is a measure of the acceptable error between the road experience of the vehicle as reported by the manufacturer and the simulation by the dynamometer during the EPA tests. As such the tolerance is a direct limit on the road load simulation error which EPA will accept and still consider the test results valid.

II. Background

The revised version of Advisory Circular 55, AC/55/A, states that if a manufacturer requests an alternate dynamometer adjustment, then the manufacturer will submit a "target" dynamometer coastdown time interval which reflects the road experience of the vehicle and a requested dynamometer adjustment which the manufacturer believes will result in a coastdown of the vehicle-dynamometer system matching the "target" time interval. The vehicle, and related test data are to be considered unrepresentative if the confirmatory vehicle-dynamometer coastdown time intervals are not within some tolerance of the reported "target" coastdown time.

The probelm is to choose an acceptable tolerance limit. This tolerance should be large enough that a manufacturer is unlikely to be penalized by the random variations among the EPA dynamometers, yet sufficiently stringent to avoid acceptance of consistently biased dynamometer power absorption requests.

III. Discussion

The data which are presented were collected since December 1, 1977. All data were obtained by using an electronic stop watch which automatically indicated the time interval required for the vehicle-dynamometer to coastdown from 55 to 45 mph. All speed measurements were obtained from the front roll of the dynamometer. This is the dynamometer roll which is connected both to the dynamometer power absorber and the mechanical flywheels used for the simulation of the vehicle inertia. This is the type of instrumentation and sensing location which is currently required in the EPA Recommended Practice for Vehicle-Dynamometer Coastdowns.

Using these techniques, data have been collected from all four dynamometers currently in service at EPA for light-duty vehicle exhaust emission certification and fuel economy measurements. Data were obtained from five vehicles, a 1969 Plymouth routinely used as an EPA warm-up vehicle, a Ford Cougar, an LTD, a Fiesta, and a Mercury Marquis. The last three vehicles were rental vehicles provided by the Transportation Research Center of Ohio.

The test procedures used and the data obtained from each of the vehicles are presented in the following subsections.

A. EPA Plymouth

The vehicle used in this test series was a 1969 Plymouth used at EPA for dynamometer warm-up. The data presented here were obtained by the Laboratory Branch personnel in their recent investigation of dynamometer variability. During this investigation the dynamometer simulated inertia was 5000 lbs. for all coastdowns. To maintain approximately the same load on the rear axle, the same driver was used for all tests, and the fuel tank was refilled after each test. Prior to the tests on each dynamometer, the vehicle was operated over two EPA Highway Fuel Economy Driving Cycles to insure warm-up of the vehicle and the dynamometer.

Three dynamometer coastdowns were conducted at each of seven nominal actual horsepowers. These data, and the mean of the three coastdown times are presented in the tables of Appendix A. The summary of these data, the mean coastdown times, by dynamometer are presented in Table 1 and plotted in Figure 1.

The range of these coastdown intervals are approximately 6 percent of the mean values. In the "worst" case, the range of the data at the nominal 15.5 actual horsepower point was 7.7 percent of the mean value at this point. The parallel nature of the dynamometer results should be noted. This strongly indicates that much of the observed variations among the dynamometers is a consistent effect which might be removed by improved dynamometer calibration or improved dynamometer technology. These variations might, however, also be the effect of changes in the tire rolling resistance caused by variations in the vehicle warm-up or variations in the drive axle load.

Table 1

1969 Plymouth

Nominal Actual Power (Hp)	Mean Coastdown Times (sec) Dyno #1	Dyno #2	Dyno #3	Dyno #4	Average Coastdown Time for all Dynos (seconds)	Range of Dyno Coastdown Times (Min-Max, sec)
15.5	13.15	13.35	12.50	12.36	12.84	0.99
14.5	13.77	13.96	13.12	13.38	13.56	0.84
13.5	14.46	14.64	13.80	14.13	14.26	0.84
12.5	15.17	15.44	14.42	14.94	15.00	1.02
11.5	15.91	16.21	15.29	15.81	15.80	0.92
10.5	16.83	17.05	16.20	16.59	16.67	0.85
9.5	17.83	17.84	17.10	17.35	17.53	0.74

1969 Plymouth

Mean Vehicle-Dynamometer Coastdown Time
versus
Nominal Actual Dynamometer Absorption Power

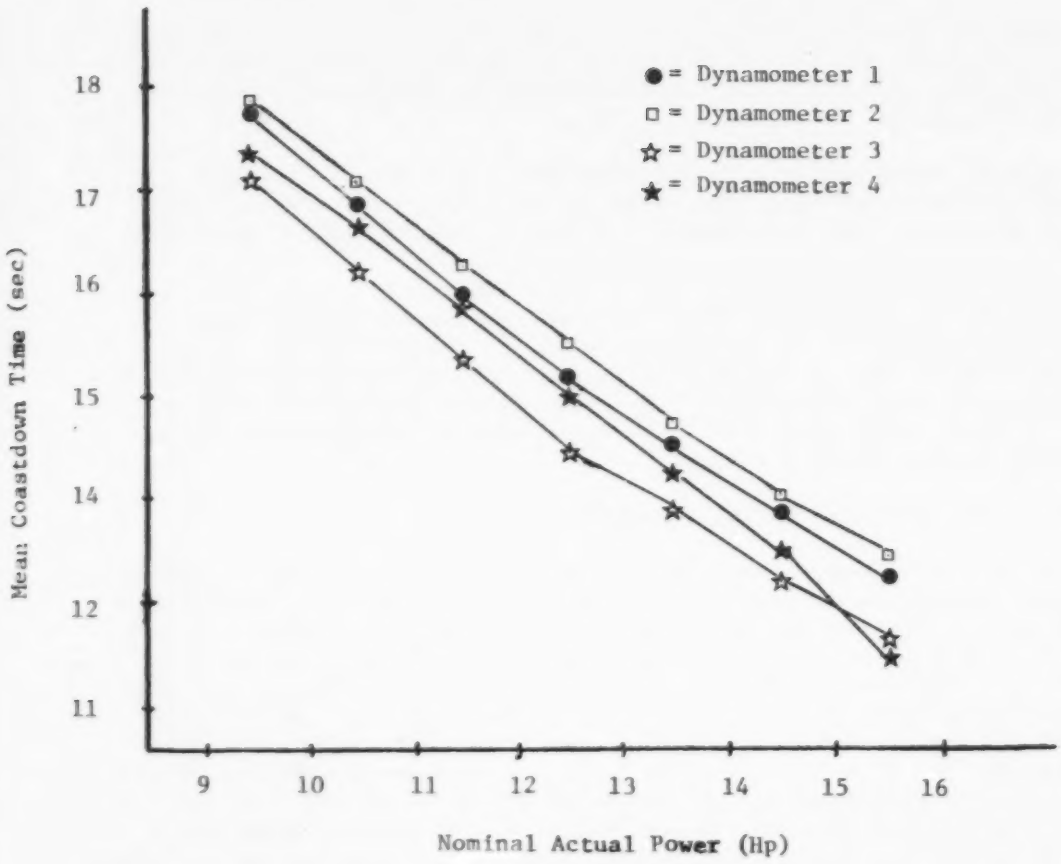

FIGURE 1

B. Ford Cougar

The Ford Cougar was a vehicle which the EPA Certification Division tested at the request of Ford. The vehicle was supplied and prepared by Ford. Rear axle load information was not obtained by EPA, however rear axle load was believed to remain constant since the same driver was used in all tests and since an auxiliary fuel tank was used during the tests.

The vehicle warm-up for these tests consisted of two EPA Highway Fuel Economy Cycles. This warm-up procedure was performed prior to each series of dynamometer coastdowns. In addition, the front roll speed calibration was checked before and after each series of coastdowns.

The individual coastdown data obtained from each dynamometer at each of the seven nominal adjustments are given in the tables of Appendix B. The summary of these data and the mean coastdown times are presented in Table 2 and plotted in Figure 2.

The range of these data are, on the average, 3 percent of the mean values. In the worst case, the range of the data at the nominal power of 12.5 horsepower was approximately 4 percent of the mean value at this point.

Again the parallel nature of the coastdown time versus actual power lines indicate much of the observed variations are systematic. The reduced range of the variations for this vehicle are probably indicative of the greater care taken in both the vehicle and dynamometer preparation prior to these tests compared to the care taken in the Plymouth tests, the first vehicle in this series.

C. Ford LTD (TRC rental vehicle)

This vehicle was a rental vehicle supplied by TRC for a recent project. This test series was designed to duplicate the vehicle and dynamometer conditions which occur during the normal certification process. In this case, the vehicle was allowed to equilibrate for at least four hours between any dynamometer tests to minimize any possible effects of systematically increasing tire temperatures. In each case the vehicle-dynamometer warm-up consisted of one EPA Urban Driving Cycle followed by two EPA Highway Fuel Economy Driving Cycles. The load on the drive axle was maintained at approximately the same level by refilling the fuel tank of the vehicle between each dynamometer sequence. No unusual dynamometer calibrations or calibration checks were performed during the test sequence. The dynamometer inertia simulation was adjusted to 5000 pounds for all tests.

Again coastdown data were obtained at each of seven nominal actual dynamometer power adjustments. These are given in the tables of Appendix C. The summary of these data and the mean coastdown times at each dynamometer adjustment are given in Table 3 and plotted in Figure 3.

Table 2

Ford Cougar

Nominal Actual Power (Hp)	Mean Coastdown Times (sec)					Average Coastdown Time for all Dynamometers (sec)	Range of Dynamometer Coastdown Times (Max-Min, sec)
	Dyno #1	Dyno #2	Dyno #3	Dyno #4	Dyno #4*		
15.5	13.22	13.42	12.93	13.00	13.17	13.15	0.49
14.5	13.97	13.95	13.56	13.64		13.78	0.41
13.5	14.55	14.56	14.06	14.16	14.40	14.35	0.50
12.5	15.08	15.20	14.62	14.78	15.14	14.96	0.58
11.5	15.94	16.08	15.62	15.73	15.91	15.86	0.46
10.5	16.67	16.96	16.52	16.66	16.86	16.73	0.44
9.5	17.80	17.69	17.17	17.15	17.74	17.51	0.65

* During the time period required for the collection of these data a routine monthly calibration of Dynamometer #4 was conducted. The tests were subsequently rerun on Dynamometer #4 to investigate the effects of this recalibration.

Ford Cougar

Mean Vehicle-Dynamometer Coastdown Time
versus
Nominal Actual Dynamometer Absorption Power

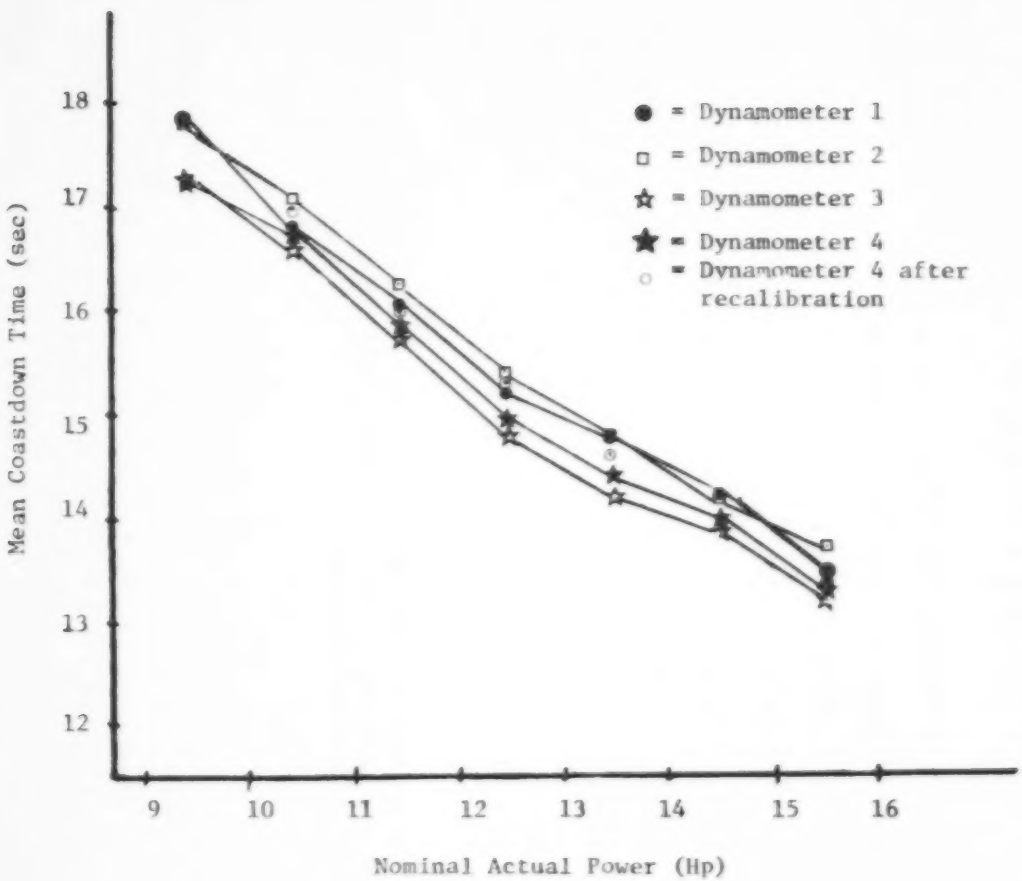

FIGURE 2

Table 3

Ford LTD (TRC Rental Vehicle)

Nominal Actual Power (Hp)	Mean Coastdown Times (sec) Dyno #1	Dyno #2	Dyno #3	Dyno #4	Average Coastdown Time for all Dynos (seconds)	Range of Dyno Coastdown Times (Min-Max, sec)
13.5	15.12	15.34	14.41	15.12	15.00	0.93
12.5	15.96	16.18	15.54	16.06	15.94	0.64
11.5	16.61	16.74	16.25	16.88	16.62	0.63
10.5	17.67	17.80	16.74	17.86	17.52	1.06
9.5	18.63	18.71	18.05	18.64	18.51	0.66
8.5	19.96	20.22	19.57	20.19	19.98	0.65
7.5	21.23	21.49	20.58	21.30	21.15	0.91

Ford LTD (TRC Rental Vehicle)

Mean Vehicle-Dynamometer Coastdown Time
versus
Nominal Actual Dynamometer Absorption Power

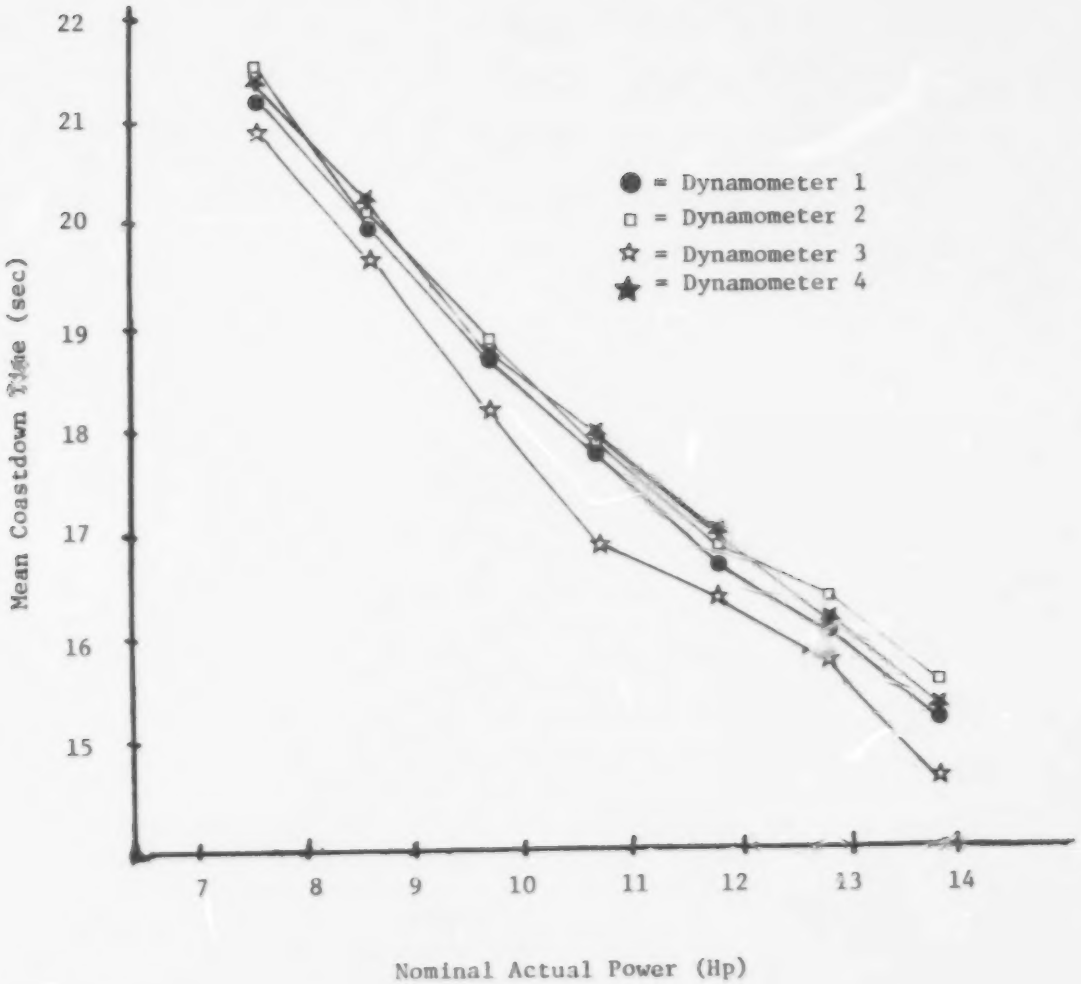

FIGURE 3

The range of the data was approximately 5 percent of the mean values. In the worst case, at a nominal 10.5 horsepower, the range of the data was 6 percent of the mean coastdwon time at this power. Again the coastdown time versus the dynamometer power adjustments are approximately parallel lines indicating there was a systematic effect between various dynamometer tests.

D. Ford Fiesta (TRC rental vehicle)

This 1978 Ford Fiesta was a rental vehicle supplied by the Transportation Research Center of Ohio. The data from this vehicle were collected in the same manner as were the data from the Ford LTD. These data are presented in Appendix D. The summary data are presented in Table 4 and plotted in Figure 4.

These data show greater variations among the dynamometers than have been observed for any of the previous vehicles. These variations were particularly severe at the lowest test powers. At these powers, 4.3 and 3.2, actual dynamometer horsepower the range of the variations were almost 14 percent of the coastdown times. It should be noted that these powers are, however, lower than currently used for exhaust emission certification or fuel economy testing at EPA. The lowest power adjustment provided by the weight based table was 5.9 Hp for a vehicle of less than 1,125 pounds. The lowest power adjustment which has been accepted as an alternate dynamometer adjustment has been 5.4 horsepower requested by Ford for the Fiesta. In the test range above 5.4 horsepower the variations were approximately 10 percent of the coastdown times. The worst case variation was 11 percent, which occurred at the nominal actual power of 5.4 horsepower.

It should also be noted that the variations in the case of the Fiesta were much more random in nature than the variations with the previous vehicle. This may indicate greater dynamometer variability in the very low power absorption regions or may indicate that variations in tire rolling resistance are more predominant. It is also possible that slight variations in the position of the drive wheels would have a greater effect in the case of front wheel drive vehicles than in the case of rear wheel drive vehicles. Since this positioning could be readily changed by test driver motion of the vehicle steering wheel, these effects might appear as random variations.

E. Ford Mercury Marquis (TRC rental vehicle)

This vehicle was also a rental vehicle supplied by the Transportation Research Center of Ohio. The vehicle test program was conducted in the same manner as the test program for the Ford LTD and the Ford Fiesta. The data are presented in Appendix E, summarized in Table 5 and plotted in Figure 5.

The variations observed in the case of the Mercury Marquis were very similar to those observed for the Cougar, and the Ford LTD. The average observed range of coastdown times, maximum minus the minimum time, was about four percent of the mean coastdown time.

Table 4

Ford Fiesta (TRC Rental Vehicle)

Nominal Actual Power (Hp)	Mean Coastdown Times (sec) Dyno #1	Dyno #2	Dyno #3	Dyno #4	Average Coastdown Time for all Dynos (seconds)	Range of Dyno Coastdown Times (Min-Max, sec)
9.7	8.24	8.39	8.43	8.71	8.44	0.47
8.6	8.89	8.56	9.06	9.38	8.97	0.82
7.6	9.98	9.57	9.22	10.17	9.73	0.95
6.5	10.45	10.20	10.69	11.02	10.59	0.82
5.4	12.48	11.70	11.28	11.87	11.83	1.2
4.3	12.60	11.60	11.95	13.33	12.37	1.73
3.2	14.26	12.97	13.60	14.89	13.93	1.92

Ford Fiesta (TRC Rental Vehicle)

Mean Vehicle-Dynamometer Coastdown Time
versus
Nominal Actual Dynamometer Absorption Power

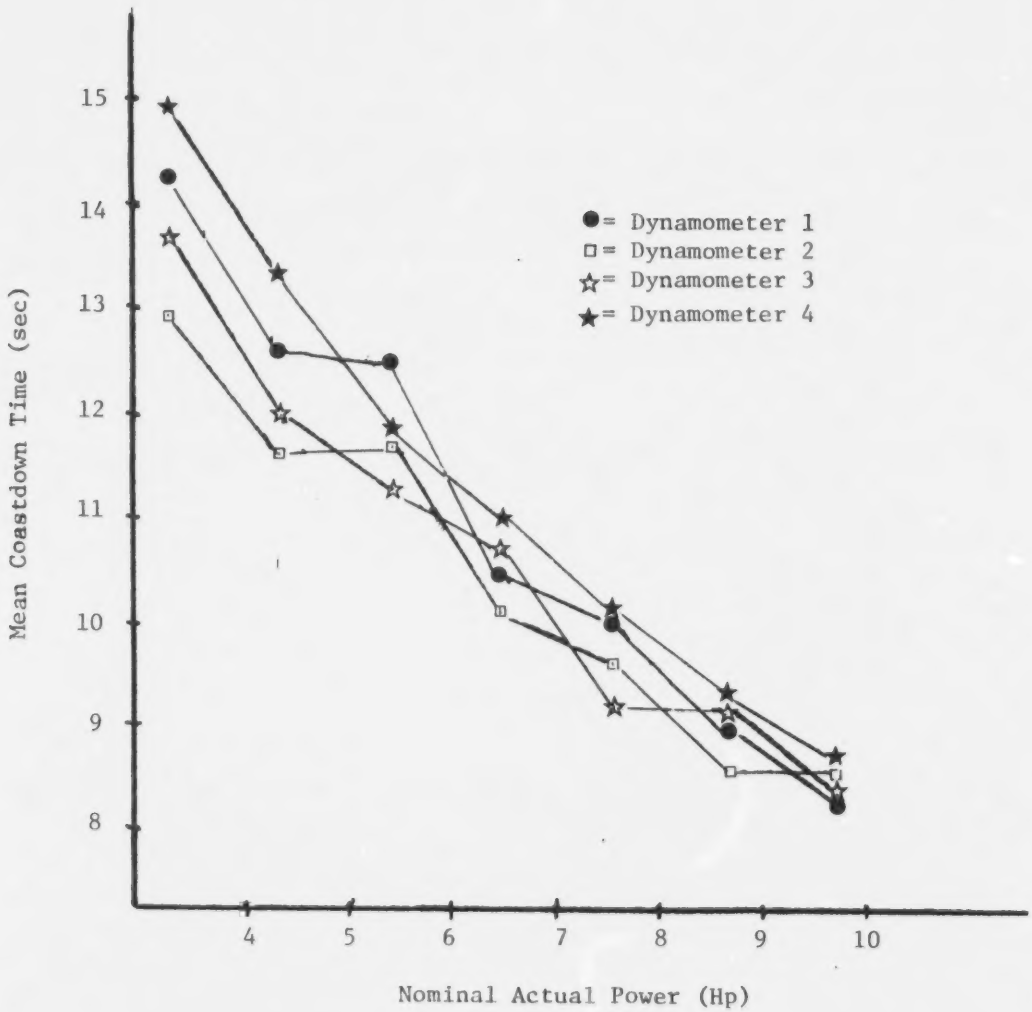

FIGURE 4

Table 5

Mercury Marquis (TRC Rental Vehicle)

Nominal Actual Power (Hp)	Mean Coastdown Times (sec) Dyno #1	Dyno #2	Dyno #3	Dyno #4	Average Coastdown Time for all Dynos (seconds)	Range of Dyno Coastdown Times (Min-Max, sec)
13.0	15.25	15.42	14.66	___	15.11	0.76
12.0	15.93	16.28	15.61	15.87	15.92	0.67
11.0	16.93	16.98	16.22	16.61	16.69	0.76
10.0	17.76	17.98	17.31	17.70	17.69	0.67
9.0	19.30	18.75	18.81	18.76	18.91	0.55
8.0	20.17	20.37	19.49	19.81	19.96	0.88
7.0	21.58	21.73	20.96	21.14	21.35	0.62

Ford Mercury Marquis (TRC Rental Vehicle)

Mean Vehicle-Dynamometer Coastdown Times
versus
Nominal Actual Dynamometer Absorption Power

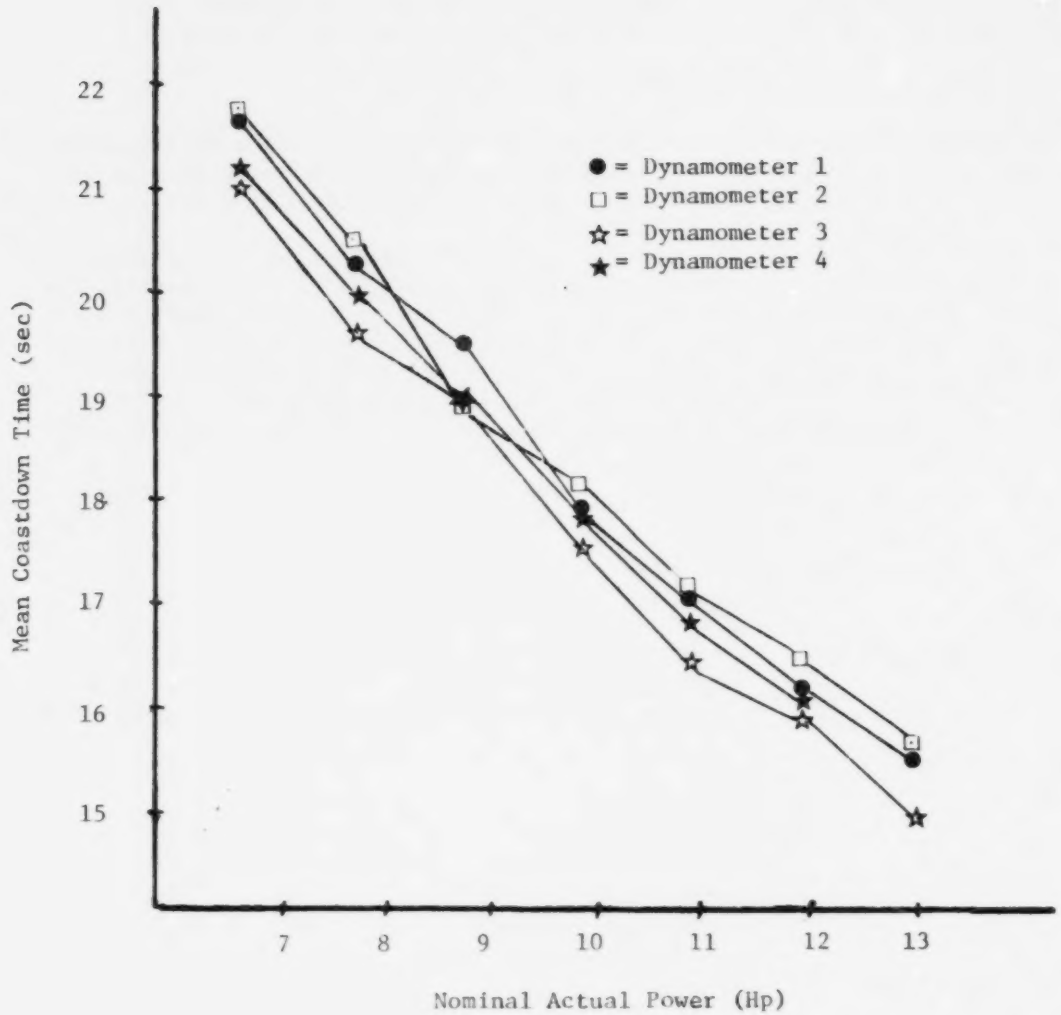

FIGURE 5

Again, the lines of dynamometer power absorption versus coastdown times for the different dynamometers are generally parallel. The exception seems to occur at a monimal power of 9 horsepower, where some convergence of the data occurs.

IV. Analysis

This section is divided into three subsections. The first subsection analyzes the observed dynamometer variability directly. The second subsection investigates the effect this dynamometer variability has on the acceptance or rejection of requests for alternate dynamometer power absorption. The third subsection summarizes the previous two.

A. Analysis of Dynamometer Variability

The vehicle-dynamometer coastdown variations observed with the Plymouth, Cougar, LTD and Marquis were similar. The variations observed with the Fiesta were greater. These results are summarized in Table 6.

In general, the range of variation for heavy conventional drive vehicles appears to be about 5 percent. The "worst case" range of variations for these vehicles was about 6%. These results are increased somewhat by the data obtained from the Plymouth which had somewhat greater variability than the data from the other rear wheel drive vehicles. The greater variability of the Plymouth data probably occurred since this was the first vehicle tested, and somewhat less care was taken with this test series.

Table 6

Summary of Dynamometer Variations
(Expressed As Percentage)

Vehicle	Average of the Observed Range of Variations [(max - min)/(mean)]100%	"Worst Case" Range of Variations [(max - min)/(mean)]100%
Plymouth	5.9	7.7
Cougar	3.3	3.9
LTD	4.5	6.2
Fiesta	10.0	14.0*
Marquis	4.1	5.1
Average for heavy conventional drive vehicles	4.5	5.7
Fiesta	10.0	14.0*

* This extreme range of variability occurred at dynamometer power absorptions lower than any value which has currently been used for EPA testing.

It should be noted that for all of the heavy conventional drive vehicles, the curves of the coastdown times versus the dynamometer power absorption were approximately parallel. In addition, the dynamometers were usually ranked in the same order. The sequential dynamometer-to-dynamometer relationships were not the same for all dynamometers, therefore, there is no reason to believe that any change in vehicle warm-up or weight variations could induce this systematic effect. The systematic nature of the dynamometer ranking strongly indicates that even the small remaining dynamometer variations can be reduced by improved calibration techniques.

In the case of the Fiesta, the variability was much greater than for the heavy conventional drive vehicles. In addition, the variability appeared more random in nature. Much of this increased variability, when evaluated as a percentage of the coastdown time, occurred because the coastdown times were shorter for this vehicle. This explains most of the increased variability observed at the larger dynamometer power absorptions used with the vehicle. In the very low power absorption ranges, however, the variations in absolute magnitude of the coastdown times were greater for this vehicle than for the remaining vehicles. This is believed to be caused by two effects.

First, this power absorption range is below the normal dynamometer power absorption range for certification tests and is not used in the dynamometer calibration. Therefore, greater dynamometer variability and potential error is expected in this region. In addition, small changes in dynamometer power absorption will have very significant changes in the coastdown time of the vehicle-dynamometer system.

Secondly, it is possible that this variability could result from random driver induced variations in the tire-roll alignment for front wheel drive vehicles. Again, small changes in the power requirements of the system could have significant effects on the coastdown times because of the lower total system power absorption.

B. The Effects of Dynamometer Variability with Respect to Acceptance or Rejection of a Request for an Alternate Dynamometer Power Absorption

The purpose of this investigation is to recommend a tolerance value for the allowable variation between the "target" coastdown time interval supplied by the manufacturer and the time interval obtained from the EPA vehicle-dynamometer confirmatory test. Tolerance values which have been suggested are 5, 7 and 10 percent of the EPA coastdown time. The potential results of each of these values will be investigated in this section.

In the first situation it is hypothesized that a manufacturer submits a true, correct value, for the dynamometer power absorption for his vehicle. The number and percentages of the times this request would be challenged is investigated. The second situation hypothesizes that a manufacturer conducts the original dynamometer power absorption determination on a

dynamometer randomly selected from a dynamometer population equivalent to the EPA dynamometers. The question is again the number of times this request would be challenged at each of the proposed tolerance levels when the confirmatory tests were conducted on randomly selected EPA dynamometers. The third situation is somewhat the opposite of the first two. In this case it is hypothesized that a manufacturer submits a dynamometer adjustment request which is inappropriate by approximately one horsepower. The question is, again, how often this request would be challenged.

1. The probability that a request for a true, correct value for the dynamometer adjustment would be rejected because of EPA dynamometer variability.

For this evaluation it is assumed that each nominal dynamometer adjustment is a true, correct dynamometer adjustment for the mean observed coastdown time. The question for this case is; if each nominal dynamometer power absorption were requested as the dynamometer adjustment cooresponding to the mean observed dynamometer coastdown time, how often would this request be rejected assuming random selection of the EPA dynamometer for confirmation testing. For example considering the first set of data from the 1969 Plymouth, Table 1, the question is would a request for a dynamometer adjustment of 15.5 horsepower submitted with a dynamometer coastdown time of 12.84 seconds be rejected when confirmatory tested on any of the EPA dynamometers.

Since it is proposed that the tolerance be unidirectional the only rejections would occur when a dynamometer yields a coastdown longer than the mean value plus the tolerance. Therefore, the sum of the mean values for the dynamometer coastdowns at each of the nominal dynamometer adjustments plus each of the proposed tolerances were calculated. The occasions when any observed dynamometer coastdown times exceeded these values were recorded. These are the instances when a true, correct mean value would be rejected in an EPA confirmatory test.

Table 7 summarizes the number of instances, based on all of the observed data, where such a rejection of the dynamometer request would occur. In the range of dynamometer power absorptions which have been used at EPA only one rejection of such a dynamometer request would occur. This rejection case was observed for the Ford Fiesta at the 5 percent tolerance value.

2. The probability of rejection when a dynamometer power absorption is determined from a dynamometer randomly selected by a manufacturer and confirmatory tested on an EPA dynamometer randomly selected.

This case assumes a manufacturer randomly selects a single dynamometer to perform the vehicle-dynamometer coastdown part of the recommended practice for Determination of Vehicle Road Load and submits the results from that dynamometer. It is further assumed that the population of the dynamometers are the same for both EPA and the manufacturer. With this

Table 7

Confirmations and Rejections of Dynamometer Requests Which are True Correct Values

Tolerance Value	Number of Confirmations	Number of Rejections	Observed Probability of Rejection+
5%	142	3*	2.1%
7%	144	1**	0.7%
10%	145	0	0.0%

* Two of the three observed failures were at power absorption settings lower than have yet been used in EPA certification or fuel economy testing.

** This failure occurred at a power absorption setting lower than any power adjustment which has yet been used in EPA certification or fuel economy testing.

\+ The observed probability of rejection is th computed ratio of the number of rejections to the total number of observation, 145.

assumption it is possible to use the results of the EPA tests to predict the probability a request for an alternate dynamometer adjustment would be rejected under these conditons since this is equivalent to the hypothetical case in which a road load determination would be performed on one randomly selected EPA dynamometer and then the confirmation test performed on a second, randomly selected dynamometer.

The test data were examined to ascertain the number of possible combinations which would result in acceptance or rejection at each tolerance level if a requested dynamometer adjustment were determined on one randomly selected EPA dyanmometer and then confirmatory tested on a second EPA dynamometer. For example, the data of the 1969 Plymouth, Table 1 first line, was examined to see if a request for 15.5 horsepower submitted with the coastdown of any of the dynamometers 1 through 4 would be rejected if confirmatory tested on any of the dynamometers 1 through 4.

Again, a unidirectional tolerance was assumed so that those vehicles with conservative dynamometer adjustment requests would not be rejected. Therefore, in this example if the coastdown time was 12.5 seconds, corresponding to 15.5 horsepower on dynamometer 3, this request would be rejected if confirmatory tested at a 5 percent tolerance value on dynamometers 1 and 2. The request would be accepeted in confirmatory tested on dynamometers 3 or 4. Likewise, a request for 15.5 horsepower corresponding to 12.36 seconds as obtained from dynamometer 4 would be rejected if confirmatory tested on dynamometers 1 or 2 at the 5 percent tolerance level, and accepted on dynamometer 3 and 4. Requests based on dynamometers 1 and 2 would be accepted if confirmatory tested on any dynamometer at the 5 percent tolerance level. Therefore, for the nominal power of 15.5 for the sixteen possible combinations of dynamometers which could be used for power absorption and subsequent confirmation, four combinations would result in rejection of the 5 percent tolerance value.

Table 8 summarizes the number of possible combinations which would result in acceptance or rejection of the submitted request at each of the three suggested tolerance values. In this instance, considering only the range of dynamometer adjustments which have yet been used at EPA rejections were observed in 3.6 and 0.9 percent of the observations at tolerance levels of 5 and 7 respectively.

3. The probability of accepting inappropriate dynamometer adjustment requests.

The previous sections discussed the possiblity of rejecting a request for an alternate dynamometer adjustment in the cases when that request was a true correct value and in the case when any inaccuracies resulted from random dynamometer variability. Naturally, the probability of rejection diminishes as the allowable tolerance increases. For this reason it may appear desireable to adopt a rather large tolerance. However, a large tolerance also means that EPA will accept data from vehicles which will have been inappropriately tested. This section considers the probability that an incorrect dynamometer adjustment request would be accepted at various tolerance levels.

Table 8

Confirmations and Rejections of Dynmometer Requests
Assuming Random Selection of both the Test and the Confirmation Dynamometers

	Possible Combinations Resulting in Acceptance	Possible Combinations Resulting in Rejection	Percent Rejected Based on Total Observations
5%	571	36*	5.9%
7%	594	13**	2.1%
10%	602	52***	0.8%

* 8 of the observed 36 failures occured at dynamometer power adjustment settings lower than any yet used for certification or fuel economy testing.

** 6 of the observed 13 failures occured at dynamometer power adjustment settings lower than any yet used for certification or fuel economy testing.

*** 3 of the observed 5 failures occured at dynamometer power adjustment settings lower than any yet used for certification or fuel economy testing.

In this section it is assumed that a manufacturer submits a correct dynamometer coast down time, but requests a dynamometer power absorption which is approximately one horsepower less than the true correct power for that coast down time. For example, in the case of the 1969 Plymouth, first line of Table 1, the assumption is that the manufacturer would submit a coast down time of 12.84 seconds as corresponding to 14.5 horsepower.

Table 9 summarizes the probabilities that such requests would be accepted because of the dynamometer variability and the tolerance values. At the 10 percent tolerance value there is greater than 90 percent probability that EPA would accept a dynamometer adjustment which was in error by approximately one horsepower. This prabability decreases as the tolerance value decreases, to 32 percent probability at a 5 percent tolerance value.

C. Summary

The choice of an acceptable tolerance value must be a compromise between the possiblity of rejecting a legitimate alternate dynamometer request versus the risk of accepting inappropriate dynamometer adjustments. Alternately stated, an undue burden should not be imposed on the manufacturers, yet the representativeness of the EPA tests must be maintained.

Table 6 demonstrates the average variability in vehicle-dynamometer coastdown times is about 4 percent for conventional vehicles and is somewhat higher, approximately 10 percent for the Ford Fiesta, a very small front wheel drive vehicle.

Table 7 gives the probability that a submitted true correct mean value for a dynamometer power absorption request and coastdown time interval would be rejected because of EPA dynamometer variability. Rejection under these conditions implies the manufacturer has performed in the best technically correct manner which can be expected, without supplying a conservative request, and is rejected because of the variability in the EPA dynamometers.

Rejection under these conditions is considered inappropriate, therefore, the 5 percent tolerance criteria is considered inappropriate, even though this would result in only about 1 percent of the currently observed test vehicles under these conditions. In the dynamometer power absorption regions currently used for EPA testing, no rejections of true mean value requests would occur at either the 7 or 10 percent tolerance value.

Table 8 may be considered as the probability that a dynamometer power absorption request and the associated coastdown time would be rejected considering the dynamometer variability of both the original test dynamometer and the confirmation dynamometer. This table indicates that, in the region of dynamometer power absorption currently used for EPA testing, there is about 1 percent probability of rejection with the 7 percent tolerance value. Furthermore, for conventional vehicles, only

Table 9

Acceptance or Rejection of Requested Dynamometer Adjustments
Differing by Approximately One Horsepower
From the Correct Value

Tolerance Value	Number of Acceptances	Number of Rejections	Percentage of Acceptances
5%	40	85	32%
7%	89	36	71%
10%	115	10	92%

two instances of a rejection were observed, indicating a probability for rejection of only 0.33 percent. The probability of rejection is of course, even less with the 10 percent tolerance value.

Table 9 provides the probability that EPA will accept an inappropriate dynamometer adjustment with each of the tolerances. This table demonstrates that if a tolerance value of 10 percent is chosen there is more than 90 percent chance of accepting dynamometer adjustment requests which are in error by approximately 1.0 horsepower. It is considered that this is an unacceptable risk for EPA. From the standpoint of test accuracy a tolerance value of 5 percent is the value which appears most desireable. Only at this level is the probability of rejecting a requested dynamometer setting which is incorrect by approximately 1.0 horsepower greater than the probability of acceptance.

At the current time a tolerance value of 7 percent is considered most appropriate. This value provides a minimal probability that EPA will reject an appropriate dynamometer request. Within the range of currently used dynamometer adjustments, no instances were observed where a true mean dynamometer adjustment would be rejected. Within the range of currently used dynamometer adjustments there is only about 1 percent probability that a dynamometer adjustment would fail a confirmation test. The very few questions which may arise can be expected to occur for very small, probably front wheel drive vehicles. Minor additional care for these small number of vehicles of this type should not impose a significant burden on either EPA or the manufacturers. For example, a manufacturer can eliminate even this small risk by determining a dynamometer adjustment from several dynamometers and requesting the mean value. It is particularly appropriate that additional care be taken in assuring the representativeness of the dynamometer test of these vehicles since the test results from such vehicles are very sensitive to variations in the dyramometer adjustment.

V. Conclusions

It is concluded that a 7 percent allowable tolerance between the submitted coastdown time and the coastdown time obtained during the EPA confirmatory test is most appropriate at this time.

It is also concluded that a 5 percent tolerance would be most desireable from the standpoint of rejecting inappropriate dynamometer requests. Several improvements in the dynamometer and in the dynamometer calibration are currently planned by the Laboratory Branch. These improvements should increase the dynamometer system accuracy sufficiently that the tighter, 5 percent tolerance value can be adopted.

VI. Recommendation

It is recommended that the tolerance value of 7 percent be adopted for the 1979 model year. It is further recommended that a tolerance value of 5 percent be tentatively proposed for the 1980 model year.

APPENDIX A

Table A-1

1969 Plymouth
Dynamometer 1
IWC = 5000 pounds
12/12/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
15.5	12.6	15.52	13.16	13.17	13.12	13.15
14.5	11.6	14.50	13.77	13.78	13.77	13.77
13.5	10.6	13.47	14.46	14.46	14.45	14.46
12.5	9.6	12.44	15.16	15.15	15.20	15.17
11.5	8.7	11.52	15.93	15.90	15.91	15.91
10.5	7.7	10.49	16.85	16.80	16.85	16.83
9.5	6.7	9.46	17.76	17.85	17.89	17.83

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9730
B = -2.5051

Table A-2

1969 Plymouth
Dynamometer 2
IWC = 5000 pounds
12/12/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
15.5	12.3	15.56	13.29	13.36	13.40	13.35
14.5	11.4	14.61	13.95	13.97	13.96	13.96
13.5	10.4	13.57	14.63	14.60	14.70	14.64
12.5	9.4	12.51	15.43	15.50	15.40	15.44
11.5	8.5	11.57	16.24	16.14	16.26	16.21
10.5	7.5	10.52	17.15	16.97	17.03	17.05
9.5	6.6	9.57	17.96	17.77	17.78	17.84

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9526
B = -2.5242

Table A-3

1969 Plymouth
Dynamometer 3
IWC = 5000 pounds
12/12/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
15.5	13.1	15.45	12.45	12.51	12.55	12.50
14.5	12.2	14.52	13.10	13.12	13.15	13.12
13.5	11.2	13.48	13.79	13.78	13.83	13.80
12.5	10.3	12.54	14.44	14.46	14.37	14.42
11.5	9.3	11.50	15.26	15.30	15.32	15.29
10.5	8.3	10.46	16.17	16.24	16.20	16.20
9.5	7.4	9.53	17.12	17.08	17.09	17.10

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9617
B = -1.7620

Table A-4

1969 Plymouth
Dynamometer 4
IWC = 5000 pounds
12/12/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
15.5	12.6	15.53	12.13	12.40	12.56	12.36
14.5	11.6	14.50	13.38	13.36	13.40	13.38
13.5	10.6	13.46	14.15	14.03	14.22	14.13
12.5	9.7	12.53	14.93	14.86	15.01	14.94
11.5	8.7	11.50	15.84	15.82	15.78	15.81
10.5	7.7	10.46	16.56	16.50	16.70	16.59
9.5	6.8	9.53	17.30	17.37	17.39	17.35

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9670
B = -2.4182

APPENDIX B

Table B-1

Ford Cougar
Dynamometer 1
IWC = 5000 pounds
12/13/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
12.5	9.6	12.44	15.06	15.07	15.11	15.08
9.5	6.7	9.46	17.78	17.82	17.81	17.80
13.5	10.6	13.47	14.59	14.51	14.55	14.55
15.5	12.6	15.52	13.21	13.21	13.25	13.22
11.5	8.7	11.52	15.94	15.95	15.92	15.94
10.5	7.7	10.49	16.62	16.64	16.74	16.67
14.5	11.6	14.50	14.04	13.91	13.96	13.97

Dynamometer Calibration
INHP = M * ACT + B
M = 0.973
B = -2.5051
Vehicle Warm-Up Started at 2:49

Table B-2

Ford Cougar
Dynamometer 2
IWC = 5000 pounds
12/13/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
12.5	9.4	12.44	15.14	15.22	15.23	15.20
9.5	6.6	9.52	17.64	17.67	17.77	17.69
13.5	10.4	13.48	14.53	14.54	14.60	14.56
15.5	12.3	15.46	13.40	13.42	13.45	13.42
11.5	8.5	11.50	16.05	16.05	16.15	16.08
10.5	7.5	10.46	16.91	16.94	17.02	16.96
14.5	11.4	14.53	13.91	13.95	13.99	13.95

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9568
B = -2.5242
Vehicle Warm-Up Started at 12:55

Table B-3

Ford Cougar
Dynamometer 3
IWC = 5000 pounds
12/14/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
12.5	10.3	12.54	14.59	14.64	14.63	14.62
9.5	7.4	9.53	17.11	17.22	17.19	17.17
13.5	11.2	13.48	14.07	14.03	14.08	14.06
15.5	13.1	15.45	12.90	12.94	12.95	12.93
11.5	9.3	11.50	15.58	15.62	15.66	15.62
10.5	8.3	10.46	16.49	16.55	16.53	16.52
14.5	12.2	14.52	13.55	13.59	13.54	13.56

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9617
B = -1.7620
Vehicle Warm-Up Started at 9:45

Table B-4

Ford Cougar
Dynamometer 4
IWC = 5000 pounds
12/13/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
15.5	12.6	15.53	12.95	13.00	13.06	13.00
14.5	11.6	14.50	13.64	13.63	13.60	13.64
13.5	10.6	13.46	14.16	14.15	14.17	14.16
12.5	9.7	12.53	14.70	14.73	14.90	14.78
11.5	8.7	11.50	15.72	15.71	15.76	15.73
10.5	7.7	10.46	16.66	16.64	16.67	16.66
9.5	6.8	9.53	17.16	17.06	17.22	17.15

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9670
B = -2.4182
Vehicle Warm-Up Started at 8:50

Table B-5

Ford Cougar
Dynamometer 4 - Repeat Test After Routine Calibration
IWC = 5000 pounds
12/14/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
12.5	9.7	12.53	15.03	15.18	15.22	15.14
9.5	6.8	9.53	17.85	17.66	17.72	17.74
13.5	10.6	13.46	14.38	14.40	14.43	14.40
15.5	12.6	15.53	13.09	13.18	13.23	13.17
11.5	8.7	11.50	15.90	15.90	15.93	15.91
10.5	7.7	10.46	16.76	16.88	16.94	16.86
15.0	12.0	14.91	13.59	13.65	13.75	13.66

Dynamometer Calibration
INHP = M * ACT + B
M = 0.967
B = -2.4182

APPENDIX C

Table C-1

Ford LTD (TRC Rental)
Dynamometer 1
IWC = 5000 pounds
12/21/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
8.5	5.7	8.43	20.01	20.02	19.85	19.96
7.5	4.7	7.41	21.12	21.35	21.23	21.23
9.5	6.7	9.46	18.64	18.66	18.61	18.63
11.5	8.7	11.52	16.60	16.63	16.60	16.61
10.5	7.7	10.49	17.61	17.72	17.67	17.67
13.5	10.7	13.57	15.06	15.16	15.13	15.12
12.5	9.7	12.54	15.94	15.97	15.98	15.96

Dynamometer Calibration
INHP = M * ACT + B
M = 0.973
B = -2.5051
Vehicle Warm-Up Started at 2:42

Table C-2

Ford LTD (TRC Rental)
Dynamometer 2
IWC = 5000 pounds
12/21/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
8.5	5.6	8.48	20.18	20.23	20.25	20.22
7.5	4.6	7.43	21.43	21.52	21.53	21.49
9.5	6.6	9.52	18.83	18.54	18.77	18.71
11.5	8.6	11.60	16.94	16.61	16.68	16.74
10.5	7.6	10.56	17.76	17.80	17.84	17.80
13.5	10.6	13.69	15.31	15.36	15.34	15.34
12.5	9.6	12.64	16.05	16.26	16.22	16.18

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9586
B = -2.5242
Vehicle Warm-Up Started at 10:15

Table C-3

Ford LTD (TRC Rental)
Dynamometer 3
IWC = 5000 pounds
12/20/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
8.5	6.4	8.49	19.61	19.68	19.41	19.57
7.5	5.4	7.45	20.49	20.55	20.69	20.58
9.5	7.4	9.53	17.95	18.03	18.16	18.05
12.5	10.4	12.65	15.54	15.52	15.56	15.54
10.5	8.4	10.57	16.60	16.77	16.86	16.74
13.5	11.4	13.69	14.22	14.46	14.56	14.41
11.5	9.4	11.60	16.24	16.23	16.28	16.25

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9617
B = -1.7620
Vehicle Warm-Up Started at 10:55

Table C-4

Ford LTD (TRC Rental)
Dynamometer 4
IWC = 5000 pounds
12/20/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
8.5	5.8	8.49	20.06	20.00	20.50	20.19
7.5	4.8	7.46	21.19	21.32	21.39	21.30
9.5	6.8	9.53	18.47	18.64	18.82	18.64
11.5	8.8	11.60	16.90	16.84	16.91	16.88
10.5	7.8	10.57	18.09	17.77	17.73	17.86
13.5	10.8	13.67	15.16	15.14	15.06	15.12
12.5	9.8	12.63	16.08	16.08	16.01	16.06

Dynamometer Calibration
INHP = M * ACT + B
M = 0.967
B = -2.4182
Vehicle Warm-Up Started at 2:45

APPENDIX D

Table D-1

Ford Fiesta (TRC Rental Vehicle)
Dynamometer 1
IWC = 2000 pounds
12/21/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
4.3	2.6	4.30	12.32	12.56	12.91	12.60
3.2	1.6	3.22	13.88	14.22	14.69	14.26
5.4	3.6	5.39	12.42	12.59	12.43	12.48
7.6	5.6	7.55	9.92	10.02	10.01	9.98
6.5	4.6	6.47	10.35	10.48	10.53	10.45
9.7	7.6	9.72	8.16	8.26	8.31	8.24
8.6	6.6	8.64	8.72	8.97	8.99	8.89

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9223
B = -1.3673
Vehicle Warm-Up Started at 1:15

Table D-2

Ford Fiesta (TRC Rental Vehicle)
Dynamometer 2
IWC = 2000 pounds
12/21/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
4.3	2.4	4.32	11.25	11.68	11.88	11.60
3.2	1.4	3.24	12.70	13.05	13.16	12.97
3.4	3.4	5.40	11.64	11.72	11.73	11.70
7.6	5.4	7.57	9.43	9.58	9.69	9.57
8.6	6.4	8.65	8.42	8.65	8.60	8.56
6.5	4.4	6.48	9.98	10.19	10.42	10.20
9.7	7.4	9.73	8.25	8.49	8.44	8.39

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9246
B = -1.5956
Vehicle Warm-Up Started at 8:30

Table D-3

Ford Fiesta (TRC Rental Vehicle)
Dynamometer 3
IWC = 2000 pounds
12/20/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
4.3	3.2	4.33	11.62	12.04	12.18	11.95
3.2	2.2	3.25	13.14	13.68	13.98	13.60
5.4	4.2	5.41	11.18	11.25	11.40	11.28
7.6	6.2	7.58	8.96	9.38	9.32	9.22
9.7	8.2	9.74	8.25	8.52	8.51	8.43
6.5	5.2	6.50	10.61	10.72	10.74	10.69
8.6	7.2	8.66	9.09	9.12	8.96	9.06

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9238
B = -0.8007
Vehicle Warm-Up Started at 1:48

Table D-4

Ford Fiesta (TRC Rental Vehicle)
Dynamometer 4
IWC = 2000 pounds
12/20/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
4.3	2.4	4.26	13.20	13.39	13.41	13.33
3.2	1.4	3.18	14.72	14.95	15.01	14.89
5.4	3.4	5.34	11.80	11.89	11.91	11.87
7.6	5.4	7.50	10.17	10.16	10.18	10.17
6.5	4.4	6.42	11.18	10.98	10.91	11.02
9.7	7.4	9.66	8.57	8.73	8.83	8.71
8.6	6.4	8.58	9.38	9.37	9.38	9.39

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9255
B = -1.5435
Vehicle Warm-Up Started at 8:00

APPENDIX E

Table E-1

Mercury Marquis (TRC Rental Vehicle)
Dynamometer 1
IWC = 5000 pounds
1/3/78

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
8.8	6.1	8.84	19.23	19.35	19.31	19.30
10.9	8.1	10.90	16.86	16.93	16.99	16.93
13.0	10.1	12.95	15.26	15.28	15.21	15.25
7.8	5.1	7.82	20.17	20.20	20.15	20.17
9.8	7.1	9.87	17.76	17.76	17.76	17.76
11.9	9.1	11.93	15.91	15.91	15.95	15.92
6.7	4.1	6.79	21.59	21.58	21.58	21.58

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9730
B = -2.5051
Vehicle Warm-Up Started at 3:05

Table E-2

Mercury Marquis (TRC Rental Vehicle)
Dynamometer 2
IWC = 5000 pounds
1/3/78

Nomiinal Actuual Poweer (Hpo)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
8..8	5.9	8.79	18.74	18.73	18.79	18.75
10..9	7.9	10.87	16.76 17.06	17.03 17.04	16.94 17.06	16.98
13..0	9.9	12.96	15.41	15.40	15.46	15.42
7..8	4.9	7.76	20.37	20.37	20.36	20.37
9..8	6.9	9.83	18.06	17.91	17.98	17.98
11..9	8.9	11.92	16.24	16.32	16.29	16.28
6..7	3.9	6.70	21.69	21.72	21.77	21.73

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9586
B = -2.5242
Vehicle Warm-Up Started at 10:45

B657/31

Table E-3

Mercury Marquis (TRC Rental Vehicle)
Dynamometer 3
IWC = 5000 pounds
12/30/77

Nominal Actual Power (Hp)	Indicated Dynamometer Power Adjustment (Hp)	Computed Actual Dynamometer (Hp)	Coastdown Times (sec) Run #1	Run #2	Run #3	Mean Coastdown Time (sec)
8.8	6.7	8.80	18.16	18.21	18.30	18.22
10.9	8.7	10.88	16.24	16.22	16.21	16.22
13.0	10.7	12.96	14.63	14.69	14.66	14.66
7.8	5.7	7.76	19.54	19.42	19.52	19.49
9.8	7.7	9.84	17.22	17.35	17.35	17.31
11.9	9.7	11.92	15.62	15.57	15.63	15.61
6.7	4.7	6.72	20.94	21.00	20.94	20.96

Dynamometer Calibration
INHP = M * ACT + B
M = 0.9617
B = -1.7620
Vehicle Warm-Up Started at 1:47